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Comparison of LUCID’s Digital Music Therapy to Generic Functional Music

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Abstract

The use of music to support mental health is gaining traction in both scientific research and clinical practice. This whitepaper compares the LUCID's digital music therapy platform to generic functional playlists for stress reduction and mood improvement. The suitability of these interventions for health and wellness applications is examined along with data from a randomized controlled trial comparing LUCID's digital music system to the most popular Spotify-curated relaxation playlist. Results indicated that LUCID's intervention was more effective at improving self-reported stress ratings (-20.5% vs. -12.3%, $p=0.05$) and two dimensions of mood: valence (11.6% vs. 3.6%, $p=0.05$) and activation (-12.6% vs. 2.4%, $p=0.01$). Considering the growing numbers of individuals experiencing mental health challenges both at and below diagnostic levels, the development and validation of self-directed interventions for stress, anxiety, and mood are meaningful. LUCID will continue conducting clinical research and developing music-based interventions in collaboration with partners in the digital health space to support higher quality of care and improved treatment outcomes.

Background

Therapeutic Effects of Music & Sound

Music has long been used to support health and wellness outcomes and is a hotbed of contemporary study. Music-based interventions have shown efficacy for diverse outcomes, including stress (Sandstrom & Russo, 2010), depression (Koelsch, 2010; Angelucci et al., 2007), and pain (Choi et al., 2018; Vaajoki et al., 2010; Shabanloei et al., 2010; Good et al., 2005; Smyth et al., 2018; Chai et al., 2020; Jangsirikul et al., 2017), and can be as effective as benzodiazepines at reducing vital signs of anxiety (Bringman, Giesecke, Thörne, & Bringman, 2009). This is partially mediated through the neurochemical effects of music, including increased levels of endogenous opioids and dopamine (Mallik, Chanda, & Levitin, 2017; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011).

Auditory beat stimulation (ABS) is a family of auditory stimuli designed to induce brainwave entrainment; meaning, neuronal activity synchronizes with the ABS frequency (Vernon et al., 2014).

See LUCID's **Science and Technology Whitepaper** for more detail on the efficacy and applications of music and sound interventions.

The Future of Music Interventions

With access to digital music services becoming more widespread globally, people are increasingly incorporating music into their daily routines for entertainment and self-improvement alike. *Functional music* - music and playlists intended to help the listener achieve a particular goal, the most popular of which include relaxation, focus, sleep, and physical performance - dominates music platforms like Spotify and Apple Music. This growing acceptance of the use of music for health and wellness is likely to encourage the uptake of more rigorous, effective, and engaging functional music interventions.

Within healthcare, personalized medicine is becoming more mainstream in many domains, including neuropsychiatric care. The integration of personalization techniques to optimize for the listener's musical preferences and their current mental, emotional, and physiological state is a natural progression from one-size-fits-all music interventions to more effective and absorptive sound-based therapeutics.

Furthermore, the use of big-data techniques to support intelligent music creation and curation is a notable lack in the music industry at present. The use of rigorous, data-driven tools for functional music production would likely improve efficacy and reduce variability in outcomes. As such, quantitative music informatics are likely to become highly relevant in functional music offerings.

Generic Functional Music

Static functional music playlists are prevalent on streaming platforms like Spotify and Apple Music, and consist of songs that are manually selected to fit a desired outcome, like relaxation, sleep, or focus.

This type of functional music is widely used, well-accepted, and highly accessible. However, there is a lack of rigor or objective process behind the creation, selection, and curation of the music used in these playlists. Though all music can be relaxing and emotive, most music is not tailored to maximally leverage those qualities in a targeted way. Generic functional playlists are also limited to a one-size-fits-all experience in which variance in preferences or responses to music between individuals, or between the same individual at different times, are not accounted for. These playlists are limited to a static experience in which no element of personalization is possible, either for the music selections that an individual is most likely to enjoy or for their current mental-emotional state. The positive outcomes of music-listening have been found to be significantly more potent when the listener finds the music selection pleasurable (David & Thaut, 1989), which a canned playlist cannot take into account. Likewise, responses to music are not time-invariant; the same music selection played while the listener is in a state of distress is unlikely to invoke the same reaction as it would if they were in a calm and sleepy state. A static playlist cannot account for such a dynamic response. Moreover, these playlists don't generally include other effective sound techniques like ABS. As a result, they are not optimized to impact specific health or wellness outcomes.

LUCID's Digital Music Therapy System

LUCID is a software platform that aims to extract the full therapeutic potential of sound and music. The essence of LUCID is an affective computing environment that consists of three core technologies:

1. A novel audio engineering technique that integrates auditory beat stimulation of varying frequencies into music
2. An affective music recommendation system that personalizes music curation for specific outcomes in real-time using biometric or psychometric measurements
3. A set of tools that uses the data and insights generated through the use of the affective music recommendation system to optimize the creation of functional music for targeted outcomes

LUCID's technology is predicated on the hypothesis that through quantitative measurement and robust machine learning techniques that incorporate personalization, functional music can be optimized to achieve more significant and predictable effects on more specific outcomes. See LUCID's **Science and Technology Whitepaper** for more detail.

This music recommendation system is designed to generate music sessions for specific therapeutic outcomes. As such, it is more likely to be effective for health and wellness applications on account of the data-driven approach to creation and curation, as well as the integration of tailored sound techniques like ABS. This approach is also more likely to be enjoyable to users on account of the personalization techniques used, leading to higher engagement. However, because this type of music intervention is not currently delivered at the same scale as generic functional music, listeners may not have the same level of familiarity as they do with one-size-fits-all playlists.

Summary

Generic functional music offerings may offer some wellness benefits due to music's intrinsic capabilities to induce emotional responses and reduce stress. However, if an auditory intervention with significant therapeutic benefits and predictable effects is desired, this option is unlikely to be well-suited to the task, based on the intrinsic limitations of human-curated music interventions. Rigorous music creation and curation methods including big data analytics, quantitative measurement, and personalization are more likely to be effective and engaging for users. See Table 1 for a comparison of LUCID's technology and other available functional music technologies.

Table 1: Overview of common delivery methods of functional music as compared to LUCID's technology.

Music intervention	Evidence	Personalization	Real-time responsivity	Burden of music selection	Measurability of methods & outcomes	Scalability
Generic functional playlists	Low	Low	None	Moderate	Low	High
Self-selected music	Moderate	High	High	High	Low	High
Music therapy	High	High	High	Low	Low	Low
LUCID's Affective Music Recommendation System	High	High	High	Low	High	High

Comparison of LUCID and Generic Relaxation Music: A Randomized Controlled Trial

Methods

Participants:

40 participants (mean age: 25.05 years, 22 males, 17 females, 1 undisclosed gender) were recruited for the preliminary data collection of this study. These participants were recruited from the general population using Prolific (www.prolific.co), a remote research platform for digital recruitment and data collection, and were pre-screened for moderate anxiety symptoms using methods and cutoffs reported in a previous study (Roberts, Hart, & Eastwood, 2016). This population was selected based on the hypothesis that a single intervention use is likely to be most effective for participants with moderate trait anxiety. Participants with low trait anxiety are more likely to present with low levels of acute anxiety, resulting in a low effect size from the intervention; as a result, a very large sample would likely be needed to observe statistically significant effects. Conversely, participants with severe anxiety may find the first use of any experiential therapy to be anxiety-inducing, and may show more consistent effects in a longitudinal study. This hypothesis was supported by the results of a previous peer-reviewed randomized controlled trial, in which the most consistent and meaningful results were observed

in participants with moderate trait anxiety following a single use of LUCID's intervention (preprint available here).

Outcome Measures:

The primary outcome measure of this study was self-reported stress, using a visual analog scale (VAS) and the question: 'Indicate how stressed you feel in this moment.'

Secondary outcome measures included the Self-Assessment Manikin (SAM) (Bynion & Feldner, 2017), which measures emotion on two axes: valence, indicating positivity/negativity, and arousal, indicating high/low activation.

Interventions:

1 - LUCID's Digital Music Therapy with Integrated ABS

LUCID's core technology is outlined in the section titled **LUCID's Digital Music Therapy**, above. In this study, participants self-assessed their current mood using the Russell circumplex model (Russell, 1908). This data was then used as input to the Music Recommendation System to curate a 24-minute selection. ABS at 4 Hz was also integrated using LUCID's patented method.

2 - Generic Relaxation Playlist

To maintain objectivity in selecting the comparator music condition, the Spotify-curated relaxation playlist with the largest number of followers was selected. This playlist, 'Calm Vibes' had over 750,000,000 followers at the time of this study. The first tracks on the playlist amounting to approximately 24 minutes were purchased and compiled into a single audio stream.

Protocol:

Participants were pre-screened using the STICSA Trait scale. They then completed the stress VAS assessment and the SAM mood assessment, and were randomly assigned to listen to 24 minutes of LUCID's Digital Music Therapy or the generic relaxation playlist. They then provided post-intervention stress VAS and SAM mood ratings.

Results:

LUCID's music intervention produced more significant reductions in stress (VAS) and activation (SAM) and more significant increases in positive mood (SAM) as compared to the generic calm playlist. (See Table 2 and Figures 2-3.) No adverse events were reported.

Table 2: Changes and comparisons in primary and secondary outcomes.

	LUCID System (n = 24)	Spotify (n = 17)	One-tailed p-value	Cohen's d
Change in stress VAS	-2.25 (-20.5%)	-1.35 (-12.3%)	0.05	0.63
Change in SAM-Activation	-0.63 (-12.6%)	0.12 (2.4%)	0.01	0.81
Change in SAM-Valence	0.58 (11.6%)	0.18 (3.6%)	0.05	0.54

Discussion:

These results support the hypothesis that LUCID's music intervention is more effective than popular generic functional playlists for outcomes including stress and mood. Coupled with the fact that LUCID's intervention is highly adaptable, including the capability of adding inputs to the machine learning models and performing transfer learning to optimize for different outcome measures, this flexible architecture presents a data-driven methodology with distinct advantages compared with conventional functional music offerings.

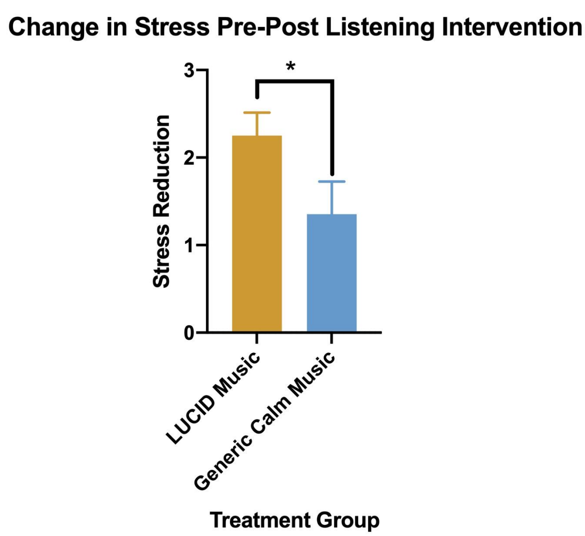

Figure 1: Reduction in stress (VAS).
(* indicates p≤0.05.)

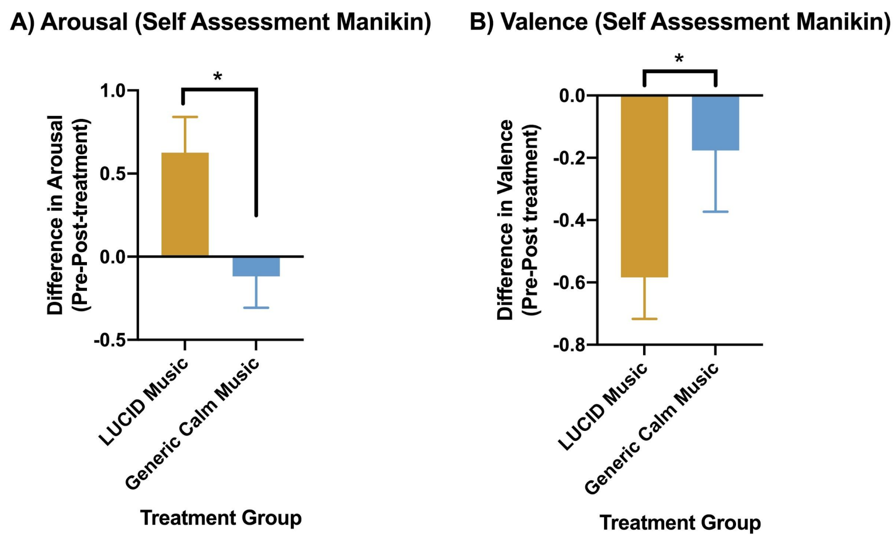

Figure 3: Reduction in Self-Assessed Mood (SAM).
(* indicates p≤0.05.)

Future Work

Though statistically significant results and good effect sizes were attained in the small randomized controlled trial comparing LUCID's digital music intervention to the top Spotify-curated calm playlist, a larger sample may be collected to achieve slightly higher effect sizes for publication purposes. If appropriate, this data may be presented at conferences and formal write-ups may be submitted to peer-reviewed journals.

More generally, LUCID intends to continue building a diverse and robust portfolio of clinical evidence. This includes a longitudinal study with biometric measures assessing effects on chronic anxiety symptoms (currently in the planning stage), a comparison of LUCID's music intervention and self-selected music, and a pilot study examining effects on anxiety in a cohort with significant chronic pain symptoms.

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